Activity 3 Volcanic Hazards: Flows

Goals

In this activity you will:

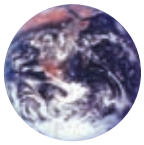
- Measure and understand how volume, temperature, slope, and channelization affect the flow of fluid.
- Apply an understanding of factors that control lava flows, pyroclastic flows, and lahars (mudflows).
- Apply understanding of topographic maps to predict lahar flow (mudflow) patterns from a given set of data.
- Describe volcanic hazards associated with various kinds of flows.
- Become aware of the benefits of Earth science information in planning evacuations and making decisions.
- Show understanding of the nature of science and a controlled experiment.

Think about It

Only one person in the entire city of St. Pierre, on Martinique in the Caribbean, survived the hot ash and rock fragments that swept over the city from the explosive eruption of Mt. Pelée in 1902. He was a prisoner in a dungeon deep underground.

- How do volcanoes affect the biosphere?

What do you think? Record your ideas about this question in your *EarthComm* notebook. Be prepared to discuss your responses with your small group and the class.



Investigate

Part A: Area of Lava Flow

1. Suppose a volcano produces twice the amount of lava than in a prior eruption. Write a hypothesis based upon the following question: What is the relationship between the volume of an eruption and the size of the area it covers?
   a) Record your hypothesis in your notebook.
2. Check your hypothesis to see if it could be disproved. A hypothesis must be a prediction that can be falsified. The statement "Some stars will never be discovered," cannot be disproved. Therefore, it is not a hypothesis.
3. In this investigation, you will use liquid soap to simulate flow during a volcanic eruption. Volcanic flows include lava, gases, and mixtures of solid particles and gases.
   a) In your notebook, set up a data table. The table should help you record the relationship between the volume of liquid soap and the surface area that the soap covers. You will do trials with 0.5, 1, 2, 4, 8, and 16 cm^3 (cubic centimeters) of liquid soap.
4. Place an overhead transparency of a square grid on a flat surface.
5. Pour 0.5 cm^3 of liquid soap onto the transparent graph paper.
6. When the soap stops flowing, measure the area of the flow.
   a) Record the area of the flow in your data table.
7. Wipe the surface clean. Repeat the trials using 1, 2, 4, 8, and 16 cm^3 of liquid soap.
   a) Record your data in your table. Look for patterns.
8. Develop a hypothesis and design a test for one of the following questions related to the flow of fluids. Remember that during scientific inquiry, you can return to the materials or your data and revise your procedures as needed.
   - What effect does temperature have on resistance to flow (viscosity)?
   - What happens to fluid when slope changes from steep to gentle?
   - What effects would you see if fluids moved through narrow channels?

   a) Write down your hypothesis.
   b) Record your procedure in your notebook.
   c) Describe the variables you investigated.
9. Present your procedure to your teacher for approval. Then run your test.
   a) Record your data.
   b) Summarize your conclusions.
   c) Was your hypothesis correct?

Heat sources can cause burns. Hot objects and liquids look like cool ones. Feel for heat at a distance before touching.

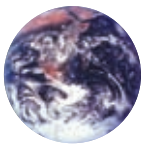
Clean up any spills immediately. Liquids being used can cause floors and equipment to be sticky or slippery.

Part B: Travel Time of Lahars

1. Examine the table of expected travel times of lahars (mudflows) triggered by a large eruption of Mt. St. Helens. The values in the table come from computer simulations and actual behavior of mudflows in the 1980 eruption.

Expected Travel Times for Lahars Triggered by a Large Eruption of Mt. St. Helens (USGS)		
Distance (via river channels) from Mt. St. Helens (km)	Estimated travel time (hours:minutes)	
	North Fork Toutle River	South Fork Toutle River, Pine Creek, Muddy River, Kalama River
10	0:37	0:11
20	1:08	0:30
30	1:37	0:54
40	2:16	1:21
50	2:53	1:49
60	3:27	2:20
70	3:48	2:53
80	4:43	3:31
90	6:36	4:18
100	8:50	5:12

2. Convert the travel times into minutes.
   a) Record the times in your notebook.
3. Make a graph of travel time (in minutes on the vertical axis) versus distance (in kilometers on the horizontal axis) for both data sets.
   a) Plot both data sets on the same graph.
   b) Connect the data points so that you can compare the data.
   c) Calculate an average velocity for mudflows along each fork of the Toutle River.
4. Answer the following questions in your notebook:
   a) Which area (North Fork or South Fork) is more likely to have a steeper gradient? Use the results of your investigation in **Activity 2** to support your answer.
   b) Explain the evidence in your graphs that suggests the gradients are not constant?
   c) Based on the information in the table, explain whether or not you think that a community located 50 km from Mt. St. Helens along either of these river valleys would have time to evacuate in the event of an unexpected massive eruption.



Reflecting on the Activity and the Challenge

In this activity, you found that temperature, volume, channels, and slope affect the flow of liquids. Analyzing data from a computer model, you predicted the flow of volcanic fluids down river valleys near Mt. St. Helens. You can now describe the volcanic hazards associated with various kinds of flows and factors which affect the flows. In your movie you may wish to locate a town in the path of a potentially dangerous flow.

Geo Words

lava flow: an outpouring of molten lava from a vent or fissure; also, the solidified body of rock so formed.

viscosity: the property of a fluid to offer internal resistance to flow.

pyroclastic flow: a high-density mixture of hot ash and rock fragments with hot gases formed by a volcanic explosion or aerial expulsion from a volcanic vent.

Digging Deeper

FLOW-RELATED HAZARDS

Lava

Lava flows are streams of molten rock that come from vents and fissures in the Earth's crust. Lava flows destroy almost everything in their path. However, most lava flows move slowly enough for people to move out of the way. Slope and cooling affect the flow of lava. Lava flows faster on a steeper slope. As lava cools, it flows less and less easily. The term **viscosity** is used to describe a fluid's resistance to flow or internal friction. As lava cools, it becomes more viscous.

Figure 1 Lava tubes form when the surface of a flow cools and crusts over, but the interior of the flow is still fluid.

Lava that is low in silica is less viscous. (See *Figure 1* in the previous activity that shows the properties of magma as they relate to magma composition.) Flows of low-silica lava can travel tens of kilometers from the source. Sometimes it sets up an internal "plumbing system." The surface may cool, crust over, and insulate the interior. This keeps the lava at a higher temperature as it moves away from the source. Evidence of this is found in the lava tubes, as shown in *Figure 1*, found in flows of low-silica lava. When lava breaks out of the leading edge of a flow, the lava can drain out. A hollow tube remains behind.

Basalt flows can move at speeds of up to 10 km/h (kilometers per hour) on steep slopes. On a shallow slope, basalt flows typically move less than one

kilometer per hour. Basaltic lava flows confined within channels or lava tubes can travel at speeds of 45 km/h. Basaltic lava flows can cover a considerable area. The largest lava flow in recent history occurred in 1783 at Laki in Iceland. Lava erupted from the Laki fissure covered 500 km^2, an area roughly equal to 100,000 soccer fields.

Since the start of the eruption in 1983, lava flows erupted from the Kilauea volcano in Hawaii and entered communities repeatedly. The flows destroyed more than 180 homes, a visitor center in a national park, highways, and historical and archaeological sites. The village of Kalapana was buried in 1990 by 15–25 m of lava erupted during a period of seven months. See *Figure 2*.

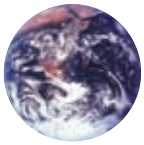
Figure 2 The former village of Kalapana was buried by lava flows.

It is sometimes possible to control the flow of lava. In 1973, lava flows at Heimaey, Iceland threatened to cut off a vital harbor. Citizens sprayed water onto the lava from ships in the harbor. This stopped the flow. Lava flows can also be diverted away from populated areas. Workers must carve a new channel or pathway through the landscape for the lava to follow.

Andesitic lava is cooler and has a higher silica content than basaltic lava. It moves only a few kilometers per hour. Andesitic lava rarely flows beyond the base of the volcano. Dacitic and rhyolitic lavas are even higher in silica and are even more viscous. Their lava usually forms steep mountains called lava domes, which extend only short distances from the vent.

Pyroclastic Flows

Topography plays a role in two other types of volcanic flows: pyroclastic flows and lahars. **Pyroclastic flows** are high-density mixtures of hot ash and rock fragments with hot gases. Pyroclastic flows occur in explosive eruptions. They move away from the vent at speeds up to 350 km/h. They often have two parts. A lower flow of coarse fragments moves along the ground. A turbulent cloud of ash rises above the lower flow. Both parts ride upon a cushion of air. This enables the material to move



Geo Words

lahar: a wet mixture of water, mud, and volcanic rock fragments, with the consistency of wet concrete, that flows down the slopes of a volcano and its river valleys.

rapidly. The more dense material follows the topography in a twisting path downslope. Pyroclastic flows are extremely dangerous. They destroy everything in their path. The pyroclastic flow produced by the Mt. St. Helens eruption, as shown in *Figure 3*, was impressive, but it was small compared to pyroclastic flows in prehistoric times.

Figure 3 Flow of pyroclastic materials from Mt. St. Helens destroyed everything in its path.

Lahar

A **lahar** is a wet mixture of water, mud, and volcanic rock fragments, with the consistency of wet concrete, that flows down the slopes of a volcano and its river valleys. Lahars can carry rock debris ranging in size from clay, to gravel, to boulders more than 10 m in diameter.

Eruptions may trigger lahars. Heat from the eruption may melt snow and ice, or the eruption may displace water from a mountain lake or river. Lahars sometimes form when the erupted material dams the mountain's drainage, causing a lake to form. The lake may spill over the loose volcanic material and send water and debris down valley. Lahars are also formed when rain soaks the loose volcanic debris during or after an eruption, causing it to start to flow. As a lahar flows downstream, it poses a risk to everyone in the valley downstream. When a lahar finally comes to a stop, it can bury an entire village under many meters of mud.

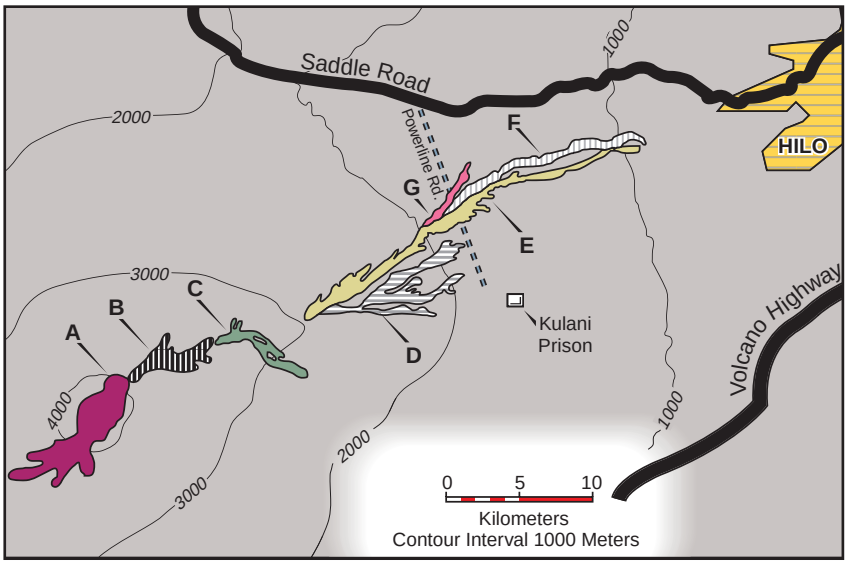
Figure 4 On the left side of the photograph, the dark region extending down the side of Mt. St. Helens is an example of a lahar flow.

Check Your Understanding

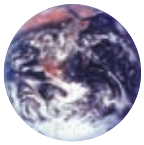
1. Name two factors that influence the viscosity of a lava flow.
2. Describe two ways in which lava flows can be controlled.
3. What is a pyroclastic flow?
4. What is a lahar?
5. How are lahars formed?
6. Explain how topography influences volcanic flows.

Understanding and Applying What You Have Learned

1. How does the volume of an eruption affect the area? Describe any mathematical pattern in your data.
2. When the Mauna Loa volcano erupted in 1984, lava flowed toward Hilo, Hawaii. It is an excellent example of how scientists used their understanding of the factors that control the flow of lava to predict where lava would flow and decide whether to evacuate residents. The map shows the path of a series of lava flows from Mauna Loa. Each flow is given a letter (A through G) in the order it happened.
   a) Look at flow D on the map. What is the elevation of the top of flow D, and what is the elevation of the Kulani Prison?
   b) How close did flow D get to the prison?
   c) Do you think that the prison was put on alert?
   d) Look at flow E on the map. The flow was channeled. Do you think it moved swiftly or slowly? Explain.
   e) Lava from flow E crossed an important road. It headed straight for the city of Hilo. The lava then broke through walls of the channel. What do you think happened to the width of the flow after it broke through the channel? How do you think this changed the speed of the flow?
3. Refer back to the reading that described the lava flow at Heimaey, Iceland.
   a) Why did spraying the lava flow with water slow it down?
   b) This was a very unusual circumstance. What factors made this effort successful?
4. Why might a lahar (mudflow of volcanic debris and water) affect a community more severely than a lava flow?



Source: USGS



Preparing for the Chapter Challenge

Think about what you have learned about volcanic flows. Prepare a one-page information sheet to raise awareness of how flows affect communities. Focus on three or more of the following:

a) How local topography controls where lava would flow.

b) Major roads that must be protected to ensure evacuation.

c) Natural and developed areas most likely to be affected.

d) Areas least likely to be affected, and why.

e) Living things that would not escape advancing flows.

f) Ways that flows might be controlled (diverting the flow, using water, and so on).

Consider how you can creatively work this information into your story line.

Inquiring Further

1. **Research a famous lava flow**

   Search the web for information about the Columbia River basalt group in the northwest. Prepare a report to the class about the members of this famous basalt group in relation to largest, longest, thickest, cooling characteristics, effects on ancient topography, and cause.

2. **Lava and the biosphere**

   How have lava flows at Mauna Loa and Kilauea volcanoes affected Hawaiian communities? How does the lava that enters the Pacific Ocean in Hawaii affect coastal ecosystems? What kinds of organisms develop and thrive at the "black smokers" along mid-ocean ridges? Research the 1783 Laki fissure flow in Iceland. It was 40 km long and covered 500 km^2. How did it affect vegetation and livestock?

3. **Lava and the cryosphere**

   What happens when lava erupts from an ice-capped or snow-capped volcano? This is an issue in the Cascade volcanoes. Mt. Rainier, which overlooks Seattle, has 27 glaciers. Some insights might be gained from exploring the recent eruption at Grimsvotn in Iceland.